U.S. Department of Energy

Light-Duty Vehicle Program Emissions Results
(Interim Results from Alternative Fuel OEM Vehicles)

by

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Synopsis

The National Renewable Energy Laboratory is managing a series of light-duty vehicle chassis dynamometer emissions tests on original equipment manufacturer alternative fuel vehicles for the U. S. Department of Energy. The goal of this program is to provide a high-quality, objective evaluation of in-use emissions from commercially available alternative fuel vehicles.

The first round of Federal Test Procedure (FTP) emissions testing of flexible-fuel methanol, ethanol, and dedicated CNG vehicles from the U. S. Federal Fleet was completed in 1995. The vehicles tested in the first round included 71 flexible-fuel M85 Dodge Spirits, 16 flexible-fuel M85 Ford Econoline vans, 21 variable-fuel E85 Chevrolet Luminas, 37 dedicated CNG Dodge B250 passenger vans, and similar numbers of standard gasoline control vehicles of each model. A summary of the interim results is presented here. This summary includes a comparison of regulated exhaust and evaporative emissions, a discussion of air toxics, and the calculated ozone-forming potential of the measured emissions. Results from the second round of testing and new alternative fuel vehicle models will be covered in upcoming publications.

Details of emissions from each fuel type were reported previously in Society of Automotive Engineers (SAE) Technical Papers 961090, 961091, and 961092. Additional information on alternative fuels in transportation is available from the Alternative Fuels Data Center (http://www.afdc.doe.gov).

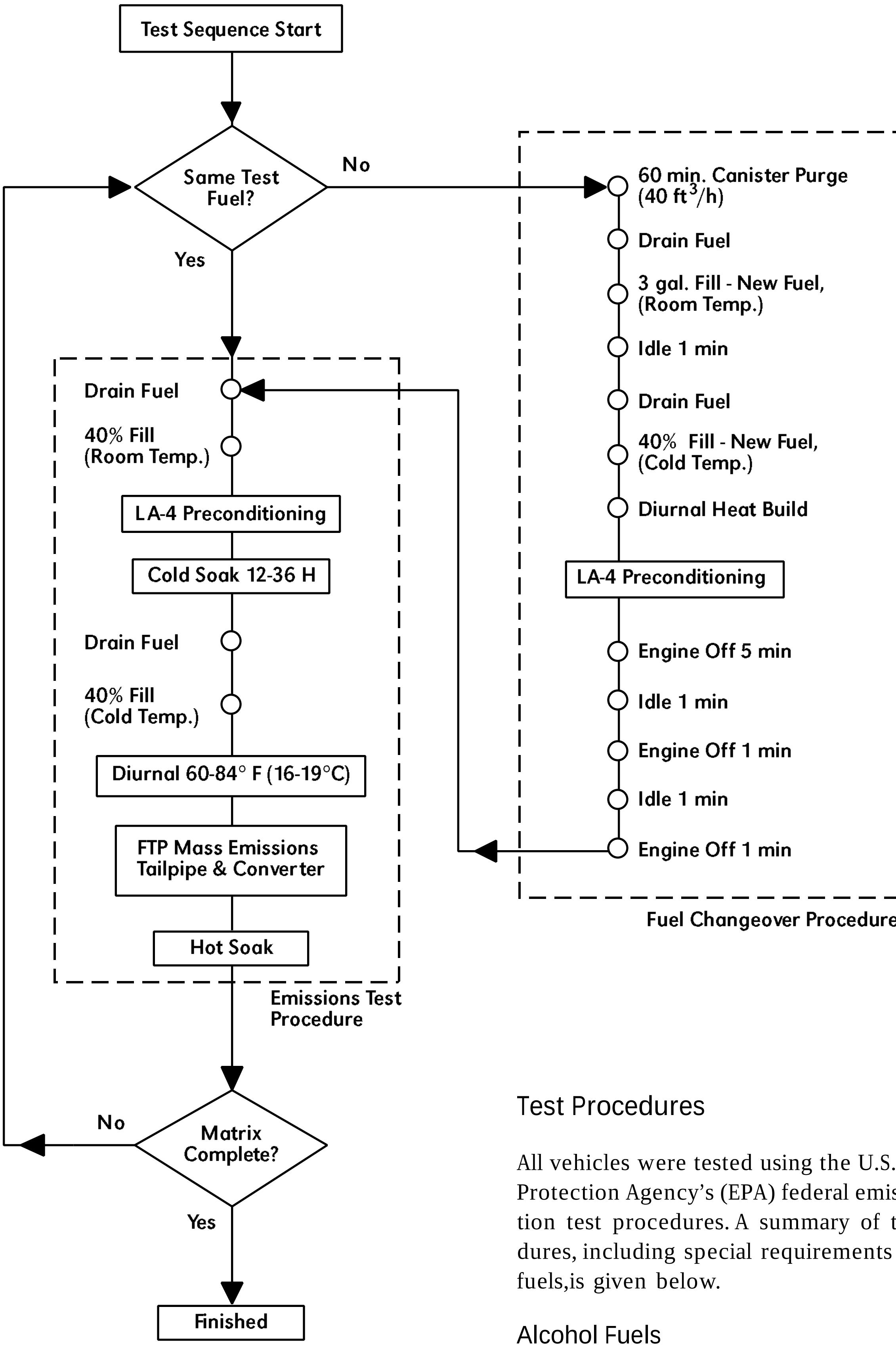


Figure 1. Vehicle testing procedure

Test Procedures

All vehicles were tested using the U.S.Environmental Protection Agency's (EPA) federal emissions certification test procedures. A summary of the test procedures, including special requirements for alternative fuels,is given below.

Alcohol Fuels

The complete procedure for testing a vehicle on alcohol fuels is outlined in Figure 1.

RFG was selected as the baseline for emissions to provide a comparison of alternative fuels to the "best" available gasoline. Each methanol flexible-fuel vehicle (FFV) was tested on reformulated gasoline (RFG), and on fuel blends including M85 (85% RFG, 15% methanol), and M50 (50% RFG, 50% methanol). Each ethanol variable-fuel vehicle (VFV) was tested on RFG, E85 (85% ethanol, 15% RFG), and E50 (50% ethanol, 50% RFG). Tests were conducted in random order. The standard gasoline control vehicles were tested on RFG. Prior to testing, a fuel changeover procedure designed to minimize the effects of switching from one test fuel to the other was followed. This consisted of a 60-min purge of the vehicle's evaporative canister with compressed air, several fuel tank drain and fill sequences, a chassis dynamometer driving prep cycle using the test fuel, and several engine start-up and idle sequences.

When the fuel changeover procedure was complete, each vehicle was tested following the EPA's Federal Test Procedures (FTP) for light-duty vehicle chassis dynamometer testing. This included a complete fuel drain and 40% refill with the test fuel at room temperature, followed by a dynamometer preconditioning driving cycle and a temperature-controlled soak for 12 to 36 h. After the soak time, the fuel was again drained and filled to 40% capacity with test fuel at 45°– 60° F. The vehicle was then pushed into the sealed housing evaporative enclosure where the EPA diurnal heat build sealed housing evaporative determination (SHED) test was performed. To determine the vehicle's evaporative hydrocarbon (HC) loss, initial and final HC measurements were taken from the evaporative enclosure as the temperature of the vehicle's fuel tank was raised from 60° F to 84° F during a period of 60 min. Within 1 h of the diurnal SHED test, the vehicle was pushed onto the dynamometer, started, and driven through the three phases of the exhaust FTP using the urban dynamometer driving schedule (UDDS, see Figure 2).

Three samples of dilute exhaust gas from the constant volume sampling system were collected during the exhaust FTP corresponding to the cold transient (Bag 1) phase, the hot stabilized (Bag 2) phase, and the hot transient (Bag 3) phase. These bag samples were analyzed for HC using a flame ionization detector (FID, heated to 235±15° F); methane, using an FID

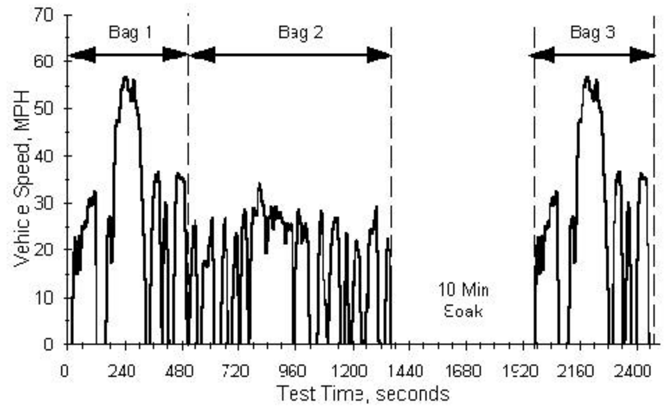


Figure 2. EPA FTP dynamometer driving cycle

combined with a gas chromatograph (GC); oxides of nitrogen (NO_X) using a chemiluminescence analyzer; and carbon monoxide (CO) and carbon dioxide (CO_2) using nondispersive infrared analyzers as prescribed by standard FTP for emissions certification. Alcohol samples are collected by drawing dilute air and exhaust gas samples through primary and secondary impingers chilled in an ice bath to 35°– 41° F. Analysis of the alcohol samples was performed by gas chromatography. Full hydrocarbon speciation was performed on approximately 15% of the test vehicles. This information was used to evaluate the exhaust toxics and reactivity of the emissions in terms of ozone-forming potential (OFP) and specific reactivity (SR).

Compressed Natural Gas

In general, the test and analytical procedures for a compressed natural gas (CNG) vehicle were very similar to those used for alcohol vehicles or standard gasoline vehicles. The major differences are due to the facts that the CNG vehicles are dedicated (i.e., they are designed to operate on CNG only), and the CNG fuel system is sealed. Because of its nature, the dedicated CNG fuel system does not include an evaporative emissions system (evaporative canister, etc.). Therefore, the evaporative canister purge procedures were not included. A modified version of the evaporative procedures was followed in order to determine the amount of CNG leakage from the fuel system. This procedure involved placing the vehicle in the standard evaporative enclosure for 1 h before and after the chassis dynamometer testing. The fuel tank was not heated as is done in the evaporative test procedure for liquid fuels. For the driving portion of the test procedure, the on-board fuel tank was shut off and a cylinder containing the test fuel was connected into the fuel system.The CNG vehicles were tested on the CNG test fuel. Matched standard gasoline control vehicles were tested on RFG. Detailed hydrocarbon speciation was performed on exhaust and evaporative emissions from approximately 15% of the vehicles tested.

Test Vehicles and Fuels

All test vehicles participating in this program were part of the U.S. federal vehicle pool leased to various government fleets through the General Services Adminstration (GSA). A large number of vehicles was selected for testing to achieve statistical confidence. Variations from vehicle to vehicle were expected to be relatively high, because vehicle service may vary widely from short delivery routes to highway driving, and the level at which the original equipment manufacturer's preventive maintenance schedule is followed depends, to a certain extent, on the diligence of the fleet operator.

Fleet personnel were notified of upcoming tests and were asked to ensure that the vehicle scheduled for testing had received normal preventive maintenance and that it was in normal operating condition. Nevertheless, each vehicle went through a general inspection when it arrived in the test laboratory. Only minor adjustments to the test vehicles (such as tightening fittings, replacement of defective gas caps, or connecting loose vacuum hoses) were performed by the emissions laboratories. Any vehicle requiring more extensive repair (for instance, if the "check engine"light was on), was returned to the fleet.

Ethanol

The ethanol test vehicles were 1992 and 1993 Chevrolet Luminas in the VFV configuration. Twenty-one VFV Luminas were tested, along with an equal number of standard gasoline Luminas. Details of the Lumina test vehicles are presented in Table 1. The VFVs are designed to run on blends of ethanol and gasoline from 85% ethanol/15% gasoline to 0% ethanol/100% gasoline. Special modifications to the VFVs include piston rings, fuel tank,engine electronic control module,high-capacity fuel injectors,corrosion-resistant fuel system materials,and an added fuel composition sensor to determine the proportion of ethanol delivered to the engine.

Table 1. Ethanol Test Vehicle General Specifications

Make	Chevrolet
Model	Lumina
Type	Passenger sedan
Model Year	1992–1993
Engine Specifications	
Displacement	3.1 liter
Horsepower	140
Configuration	V-6
Compression ratio	8.8:1
Fuel injection	Multipoint

Three test fuels, blended specifically for this program by Phillips Petroleum Company, were used in the ethanol testing.California Phase 2 RFG was specified to represent a modern gasoline baseline to compare to the ethanol blends.Ethanol blends of 50 volume % and 85 volume % were prepared by blending neat ethanol with the same California Phase 2 RFG.

Vehicles were selected from the general fleet population in the Washington, D.C., and Chicago metropolitan regions.

Methanol

Seventy-one flexible-fuel M85 1993 Dodge Spirits and 16 flexible-fuel M85 1994 Ford Econoline vans were tested, along with a similar number of standard gasoline Dodge Spirits and Ford Econoline vans. The FFV models are designed to run on blends of methanol and gasoline from 85% methanol/15% gasoline to 0% methanol/100% gasoline. It should be noted that the FFV Dodge Spirits are EPA-certified production vehicles, while the FFV Ford Econoline vans are uncertified prototype demonstration vehicles. Both vehicle designs include methanol-compatible materials in the fuel system, a special fuel sensor to measure the percentage of methanol in the fuel, higher capacity fuel flow injectors, and the appropriate changes to the engine computer programming. Vehicle specifications are shown in Table 2.

As with the ethanol testing, three specially blended test fuels were supplied by Phillips and used in the methanol testing. The base gasoline reference fuel was California Phase 2 RFG. Methanol blends of

Table 2. Methanol Test Vehicle General Specifications

Make	Dodge	Ford
Model	Spirit	Econoline E150
Type	4-door sedan	Full-size passenger van
Model year	1993	1992–1993
Engine Specifications		
Displacement	2.5 liter	4.9 liter
Horsepower	100	145
Configuration	In-line 4-cylinder	In-line 6-cylinder
Compression ratio	8.9:1	8.8:1
Fuel injection	Multipoint	Multipoint

50 volume % and 85 volume % were prepared by blending neat methanol with the same California Phase 2 RFG.

Vehicles were selected from the general federal fleet population in the Washington, D.C., New York City, Detroit,Chicago,and Denver metropolitan regions.

Compressed Natural Gas

Seventy-five Dodge B250 vans,of which 37 were dedicated CNG models, and 38 were standard gasoline controls, were tested. The test vehicles were 1992 and 1994 model year full-size, 15-passenger vans. Both the CNG and gasoline models were configured with 5.2-liter, V-8 engines, multipoint fuel injection systems, and 4-speed automatic transmissions. The CNG vehicle is equipped with a special natural gas catalyst designed for low emissions. General vehicle characteristics are summarized in Table 3.

Uniformly blended CNG fuels were prepared for use in the emissions testing program.The blended CNG is designed to represent U.S. industry-average fuel composition, and contains 93% methane. California Phase 2 RFG was used in the control vehicles. The CNG vehicles were in regular fleet service in the Washington, D.C.,and Denver regions.

Ethanol Results and Discussion

The following discussion presents a comparison of the average regulated exhaust emissions including HCs, CO, NO_X, evaporative HC emissions, nonregulated emissions such as exhaust toxic emissions, and the

Table 3. 1992/1994 Dodge B250 Van Test Vehicle Specifications

Fuel Type	CNG	Gasoline
Vehicle type	Full-size passenger van	Full-size passenger van
Engine specifications		
Displacement	5.2 liter	5.2 liter
Horsepower	230	230
Configuration	V-8	V-8
Compression ratio	8.9:1	8.9:1
Fuel injection	Multipoint	Multipoint
Fuel tank capacity	11.1–15.7 equivalent gallons	35 gallons

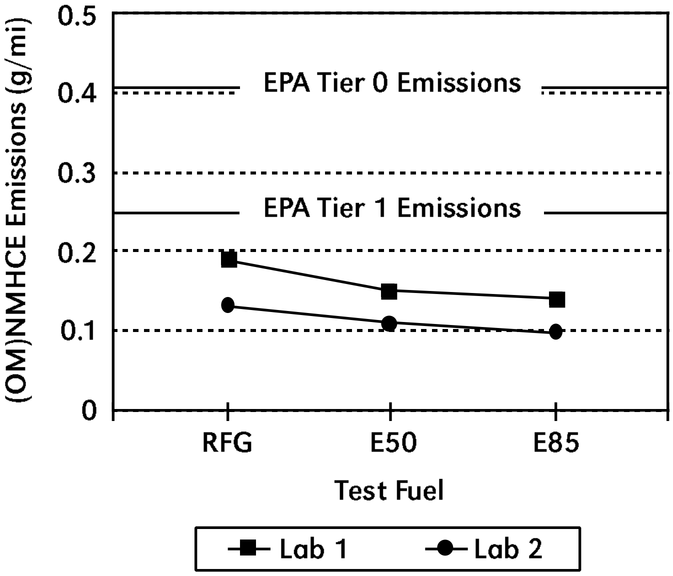


Figure 3. Lumina VFV NMHC (OMNMHCE) exhaust emissions

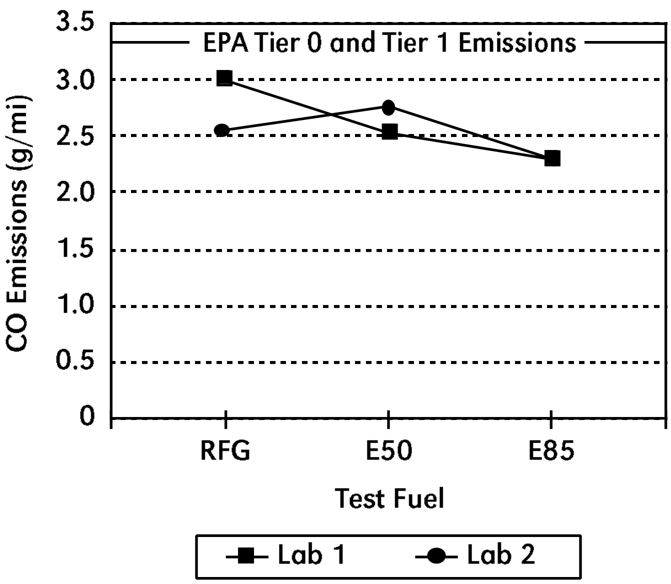


Figure 5. Lumina VFV CO exhaust emissions

ozone-forming potential (OFP) of the exhaust emissions. Ethanol fuel vehicle exhaust and evaporative HCs are regulated by the EPA as organic material HC equivalent (OMHCE). Non-methane hydrocarbon exhaust emissions are regulated by the EPA as organic material NMHC equivalent (OMNMHCE).

EPA-Regulated Exhaust Emissions

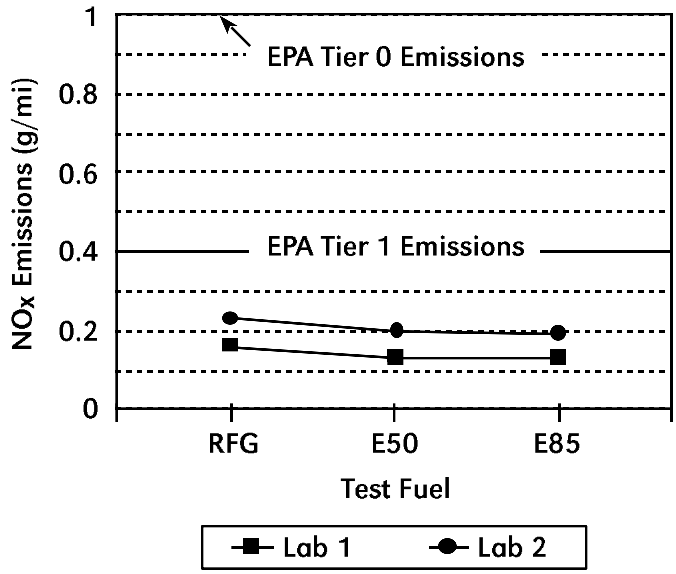


Figure 4. Lumina VFV NO_X exhaust emissions (g/mi)

EPA-Regulated Exhaust Emissions

Average non-methane hydrocarbons (NMHC), NO_X, and CO results for VFV Luminas operated on RFG, E50, and E85 are summarized in Figures 3, 4, and 5, respectively. Equivalent NMHC emissions for the ethanol fuel blends are expressed as OMNMHCE.

NMHC emissions were reduced using E85 compared to RFG by 20% at Lab 1 and by 22% at Lab 2. NO_X emissions were reduced by 25% and 32%, respectively, for E85 at the two laboratories, and CO was reduced in the E85 case by 24% and 12%, respectively, at the two laboratories.

Ethanol Evaporative Emissions

Average results for evaporative emissions from VFV Luminas operated on the three test fuels are plotted in Figure 6. As expected from the equivalent Reid vapor pressure blends, little difference was noted between RFG and E85.

Speciation of Hydrocarbon Emissions

Speciation, or quantification of individual HC emissions components through gas chromatography, was performed on two VFVs and one standard Chevrolet Lumina. This information was used to evaluate the exhaust toxics and reactivity of the emissions in terms of OFP and specific reactivity (SR).

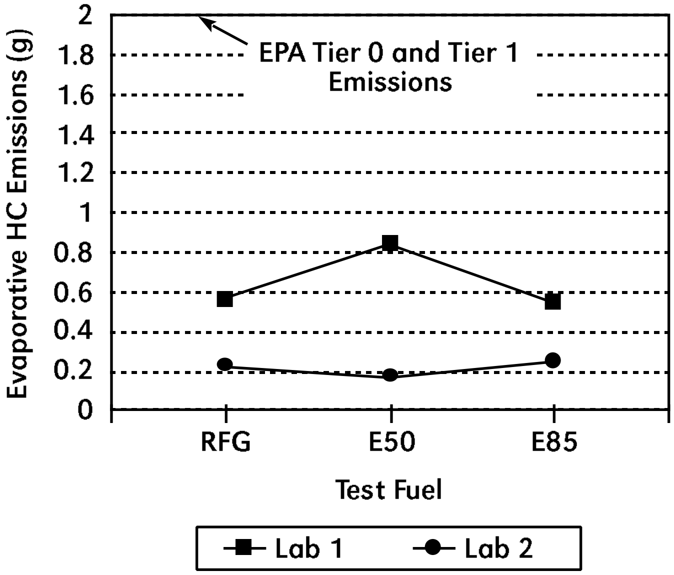


Figure 6. Lumina VFV evaporative emissions (g/test)

Exhaust Toxics

Figure 7 presents the mobile source toxics results measured at Lab 1. E85 operation compared to RFG effected a 79% reduction in benzene emissions and an 80% reduction in 1,3-butadiene. E85 operation resulted in a 20% increase in formaldehyde emissions and nearly a 20-fold increase in acetaldehyde emissions. Acetaldehyde is a primary decomposition product from ethanol combustion and is expected to be higher from ethanol than from other fuels.

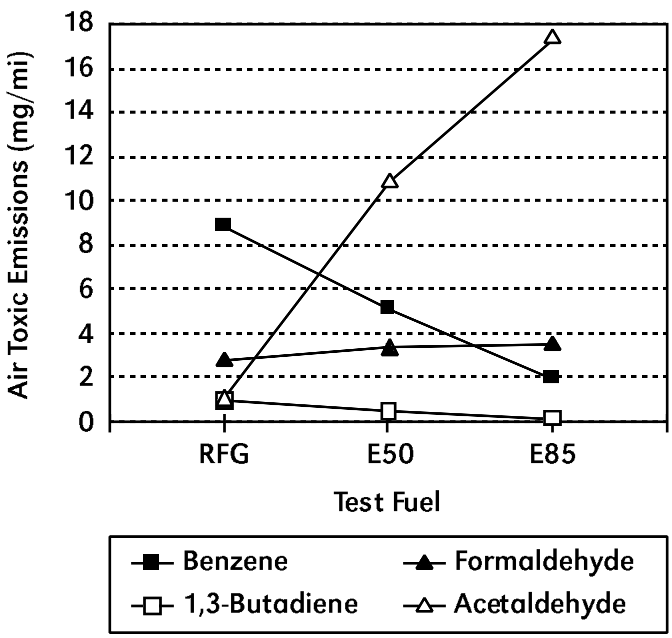


Figure 7. Lumina VFV exhaust toxics (mg/mi)

Ozone-Forming Potential and Specific Reactivity

California emissions regulations assign a maximum incremental reactivity (MIR) value to individual compounds emitted in exhaust. The MIR value is the predicted impact of the compound on ozone formation in certain urban atmospheres and is expressed in units of milligrams of ozone per milligrams of compound.

Taking into account the MIR values for all measured exhaust compounds, an OFP for the fuel may be calculated in units of milligrams of ozone per mile. SR for a given fuel may also be calculated by combining the respective mass of compound emissions per mile with the OFP, which results in units of milligrams of ozone per milligram of total organic emissions. In the California regulations, SR is based on non-methane organic gas (NMOG) emissions.

OFP is plotted in Figure 8 and SR results for the three test fuels are shown in Figure 9. Changing from RFG to E85 operation in the Lumina VFV results in a 25% reduction in OFP and a 30% reduction in SR, indicating benefits for ethanol in controlling urban ozone in some locations.

Ethanol Summary of Results

Table 4 summarizes the average results of the AMFA emissions testing of in-service Chevrolet Luminas

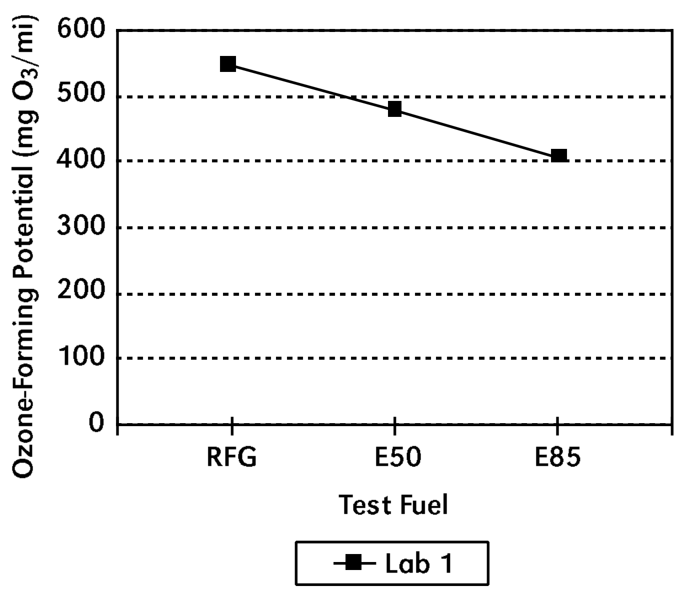


Figure 8. Lumina VFV ozone-forming potential (mg/O_3/mi)

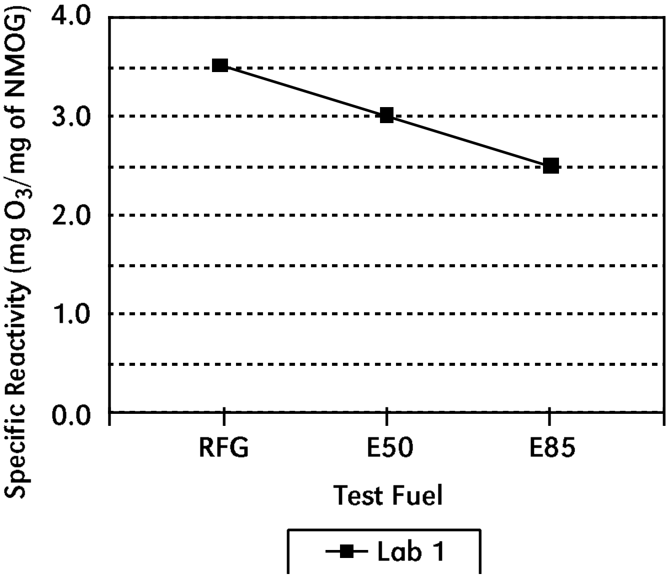


Figure 9. Lumina VFV specific reactivity (mg O_3/mg of NMOG)

operating on ethanol blends and RFG. Conclusions from the test program are preliminary, as the vehicles are still being tested at higher mileage accumulation points.

Methanol Results and Discussion

The following discussion presents a comparison of the average regulated exhaust emissions including HCs, CO, NO_X, evaporative HC emissions, nonregulated emissions such as exhaust toxic emissions, and the OFP of the exhaust emissions. Methanol fuel vehicle exhaust and evaporative HCs are regulated by the EPA as OMHCE. Non-methane hydrocarbon exhaust emissions are regulated by the EPA as OMNMHCE.

EPA-Regulated Emissions from Dodge Spirits

Figure 10 clearly shows that the average regulated emissions results from Dodge Spirit FFVs were quite low compared to the certification standards. Although these vehicles were certified to Tier 0 emissions certification standards, the average emissions were substantially lower than the more stringent Tier 1 standards for all three fuels. The average NMHC and OMNMHCE (see Figure 10a) emissions from all Dodge Spirits tested were approximately 70% lower than the Tier 0 emissions standard and approximately 50% of the more stringent Tier 1 standards.

*Table 4. Summary of Effects for E85 Compared to RFG**

Regulated Emissions	Lab 1	Lab 2
NMHC (OMNMHCE)	-20%	-22%
NO_x	-25%	-32%
CO	-24%	-12%
CO_2	-7%	-6%
Evaporative HC	-3%	0%
Fuel economy (equivalent energy basis)	+1%	-1%
Toxics		
- Benzene	-79%	
- 1,3-Butadiene	-80%	
- Formaldehyde	+20%	
- Acetaldehyde	+1949%	
Specific Reactivity	-30%	
Ozone-Forming Potential		-25%

*Note that negative values represent a reduction in emissions from E85 over RFG, and positive values represent an increase.

At Labs 1 and 3,the FFVs tested on alcohol fuels tended to have 20% to 30% lower NMHC emissions compared to the FFVs tested on RFG.

In general, Labs 1 and 3 agreed well with exhaust emissions from FFVs, showing a decrease in NMHC, an increase in NO_X, and very little change in CO. Lab 2 showed very little difference (less than 10%) between fuels for NMHC and NO_X, and a small (13%) increase in CO for M85 over RFG.

The average evaporative HC emissions (see Figure 10d) were also considerably lower than the certification standard.The results for M85 and RFG from the three laboratories agreed quite well and show very little difference between the two fuels.

EPA-Regulated Emissions from Ford Econoline Vans

A smaller number of prototype FFV Ford Econoline vans was available for testing at Labs 2 and 3 only. Figure 11 shows the average FFV regulated emissions results for Econoline vans were quite low compared to the EPA certification standards for heavy light-duty trucks. NMHC and CO values were approximately 80% lower than the Tier 0 standard, and 60% lower than the Tier 1 standards. The NO_X results were

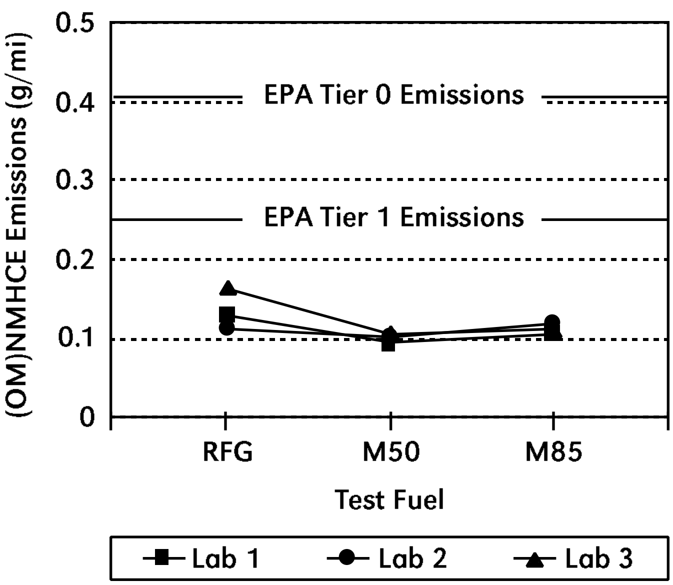


Figure 10a. OMNMHCE emissions (g/mi)

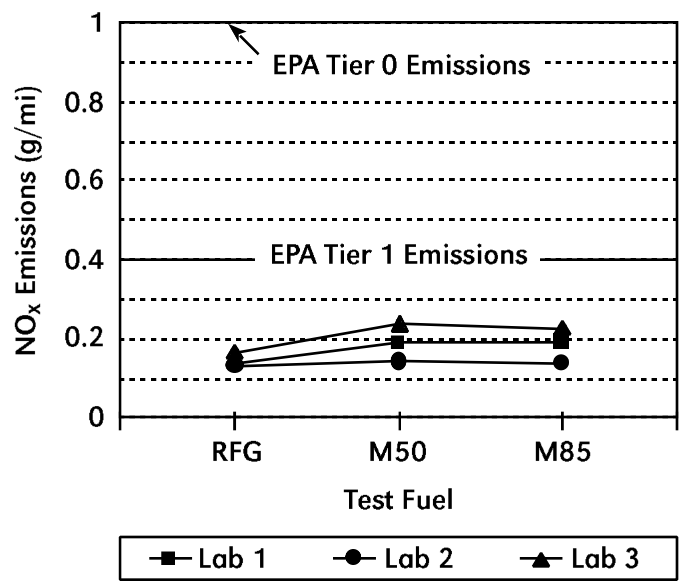


Figure 10b. NO_X emissions (g/mi)

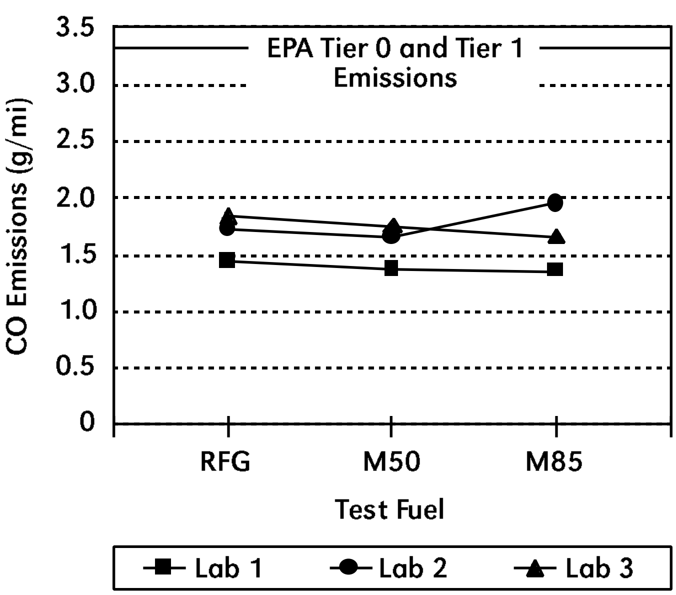


Figure 10c. CO emissions (g/mi)

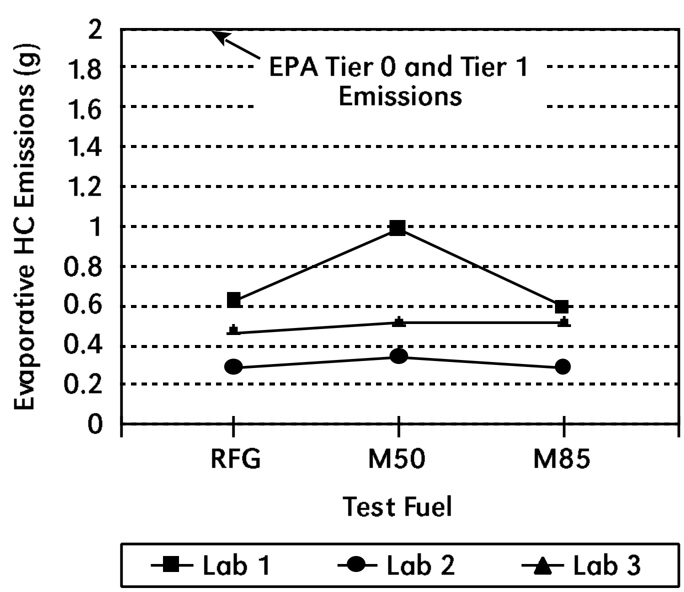


Figure 10d. Evaporative emissions (g)

approximately 50% lower than the Tier 0 and 30% lower than the Tier 1 standards. When comparing emissions from M85 tests to the RFG test results, Lab 3 showed a 21% decrease in NMHC, a 40% decrease in CO, and a 31% increase in NO_X. Results from Lab 2 showed a 25% reduction in CO, and practically no difference in NMHC or NO_X.

The average evaporative HC emissions (see Figure 11d) were approximately 85% below the 2.0 g certification standard. Both labs showed similar trends between fuels.The average M85 evaporative emissions were approximately 18% lower than the RFG from the FFVs.

Speciation of Hydrocarbon Emissions

Speciation, or quantification of individual HC emissions components through gas chromatography, was performed on six Dodge Spirits tested at Labs 1 and 3, and two of the 10 Ford Econoline vans tested at Lab 3.

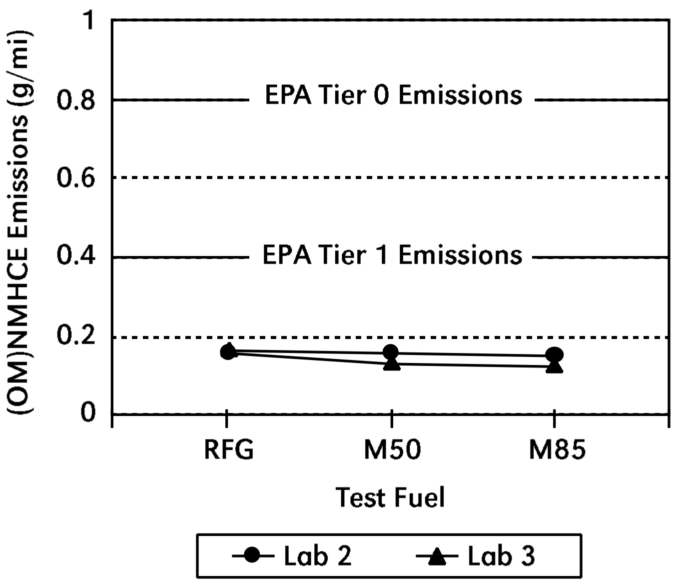


Figure 11a. OMNMHCE emissions (g/mi)

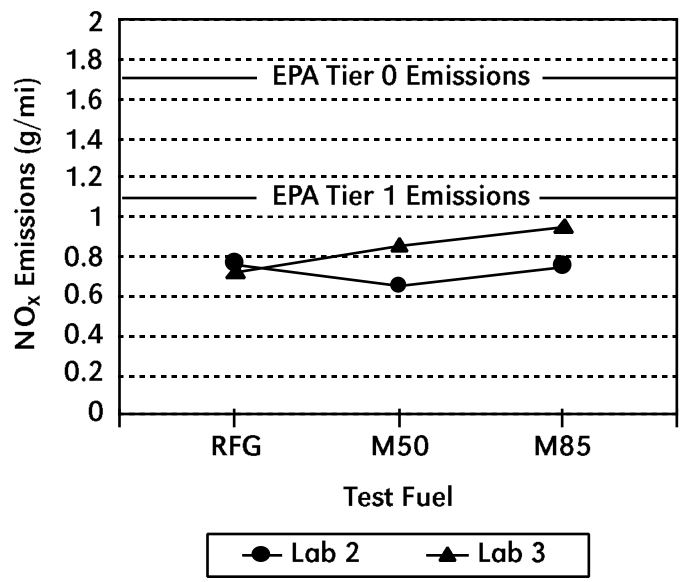


Figure 11b. N O_X emissions (g/mi)

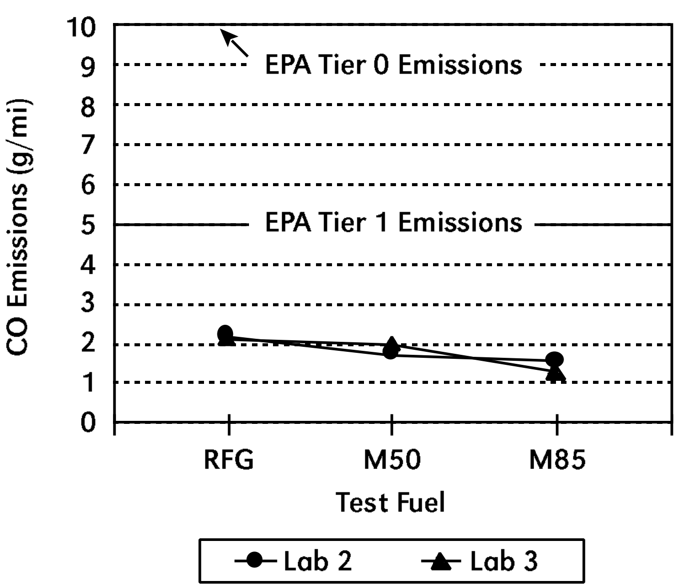


Figure 11c. CO emissions (g/mi)

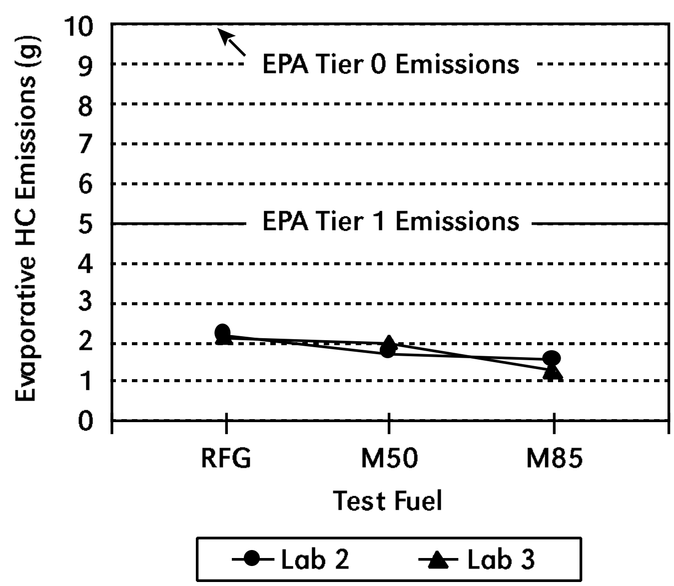


Figure 11d. Evaporative emissions (g)

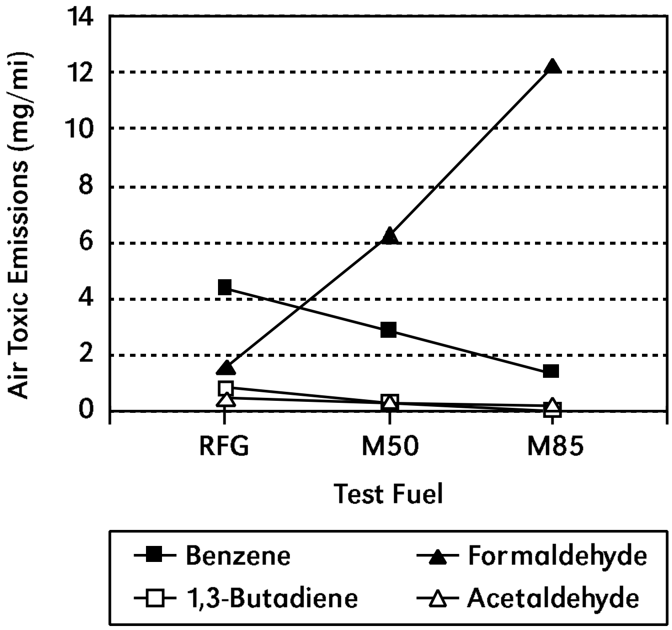


Figure 12a. Air t oxins for Dodge Spirits

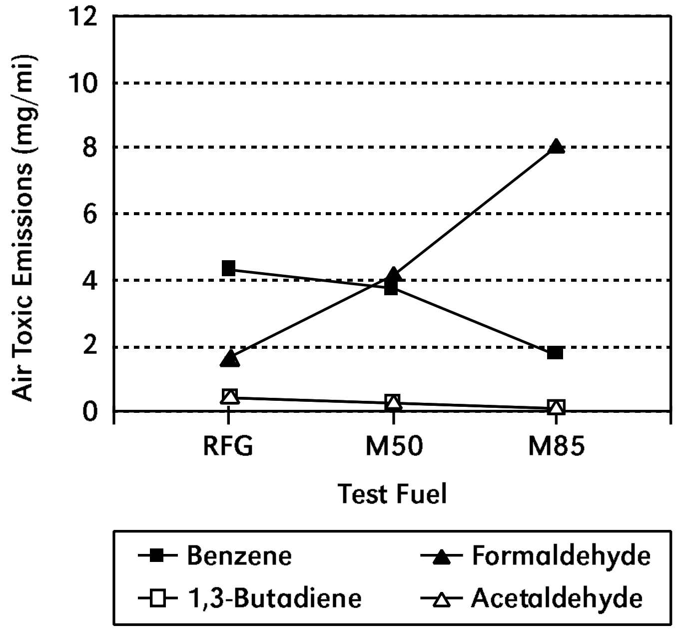


Figure 12b. Air t oxins for Ford Econoline vans

Exhaust Toxics

Figure 12 shows the average emissions values of four HC components considered to have adverse effects on human health. The compounds covered include 1,3-butadiene, benzene, formaldehyde, and acetaldehyde. Formaldehyde is a primary decomposition product from methanol combustion and is expected to be higher from methanol than from other fuels.In comparing the M85 to RFG air toxic emissions for the FFV Dodge Spirits,there was an 88% reduction in 1,3-butadiene, a 69% reduction in benzene, and a 42% reduction in acetaldehyde. The formaldehyde emissions were nearly an order of magnitude higher for M85.Results for the two FFV Ford Econoline vans are similar.The 1,3-butadiene emissions were reduced by 78%, benzene by 61%, and acetaldehyde by 63%, but formaldehyde increased 449% for the M85 tests compared to the RFG tests.

Ozone-Forming Potential and Specific Reactivity

Figure 13 presents the OFP and SR for the Dodge Spirits and Ford Econoline vans. Both laboratories

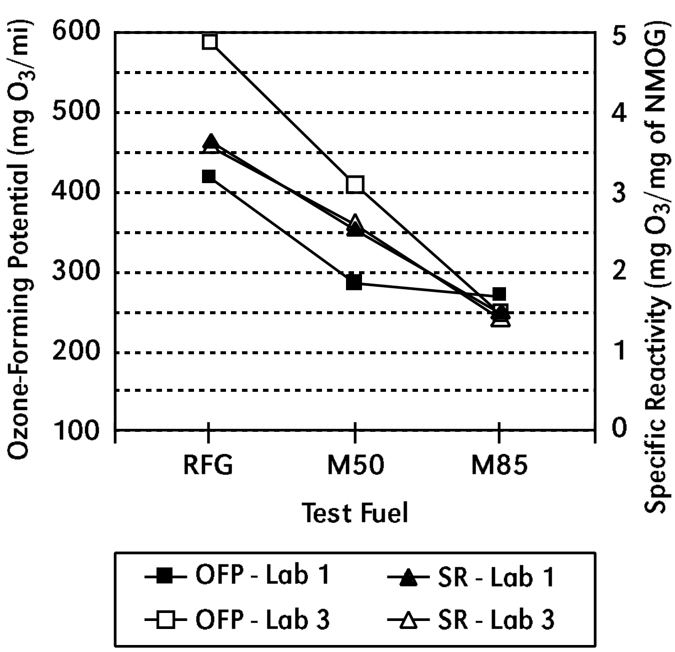
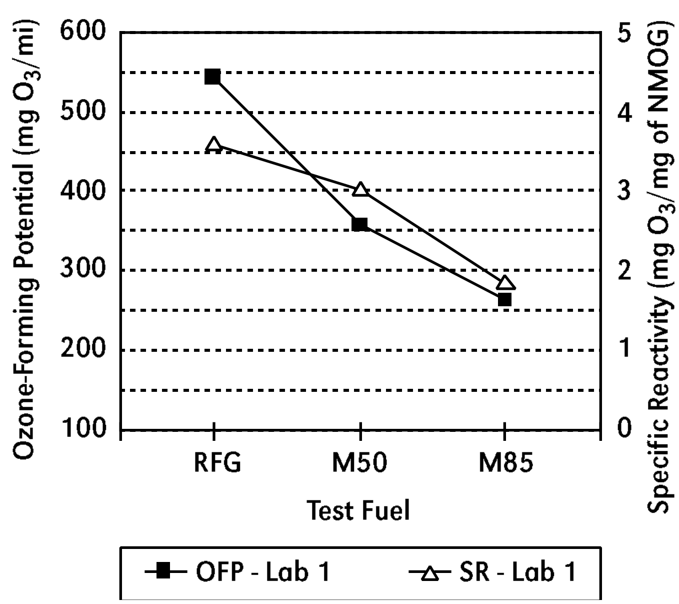


Figure 13a. OFP and SR for Dodge Spirits



Figur e 13b. OFP and SR for F ord Econoline v ans

Table 5. Summary of Effects for M85 Compared to RFG Tests on FFVs *

	Dodge Spirit			Ford Econoline	
	Lab 1	Lab 2	Lab 3	Lab 1	Lab 2
Regulated Emissions					
(OM)NMHCE	-17%	6%	-32%	-2%	-21%
NO_X	34%	8%	37%	-3%	31%
CO	-3%	13%	-9%	-25%	-40%
Evaporative HC	-4%	4%	-10%	-27%	-8%
Toxics					
- Benzene	-68%		-73%		-61%
- 1,3-Butadiene	-88%		-89%		-78%
- Formaldehyde	743%		587%		449%
- Acetaldehyde	-43%		-48%		-42%
Specific Reactivity	-60%		-61%		-51%
Ozone-Forming Potential	-36%		-58%		51%

*Note that negative values represent a reduction in emissions from M85 over RFG, and positive values represent an increase.

showed a significantly reduced OFP for FFVs tested on the alcohol fuels versus RFG. For the FFV Dodge Spirits, Lab 1 showed a 36% reduction and Lab 3 showed a 58% reduction in OFP when tested on M85 compared to RFG.

Methanol Summary of Results

Table 5 summarizes the average results from the first round of AMFA emissions testing of in-service methanol FFV Dodge Spirits and Ford Econoline vans. Overall, the emissions levels from all vehicles tested were substantially lower than the EPA Tier 0 certification levels, and most were even much lower than the more stringent Tier 1 levels. Changes in regulated emissions from fuel to fuel were relatively small, but the OFP and most toxic constituents were considerably lower when comparing M85 to RFG.

Compressed Natural Gas (CNG) Emissions Results

Exhaust Emissions

Comparisons of the CO, NO_X, and NMHC average emissions measured by the two labs on the two types of vehicles are presented in Figures 14 through 16. The corresponding Tier 0 and Tier 1 federal standards are shown superimposed on the figures.

In comparing CNG emissions to the RFG emissions, the relative results from Lab 1 and Lab 2 were in agreement for CO, NO_X, and NMHC. For these

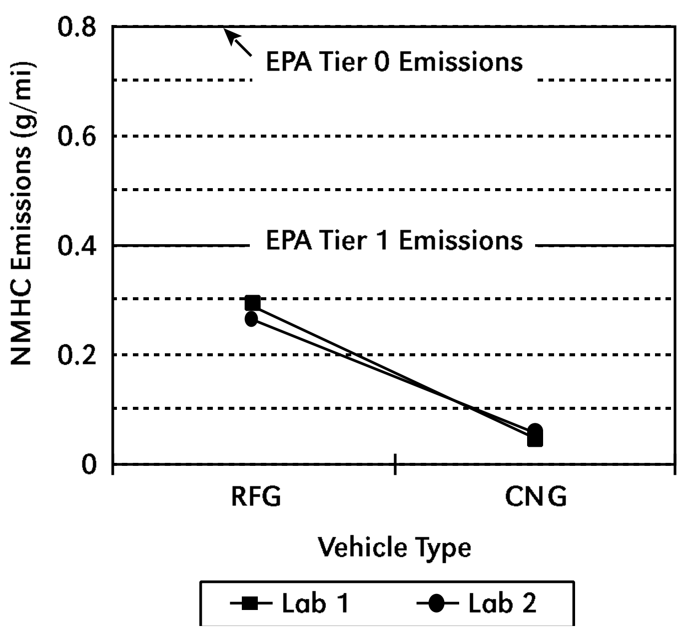


Figure 14. Comparison for NMHC emissions from the two types of vehicles, by lab

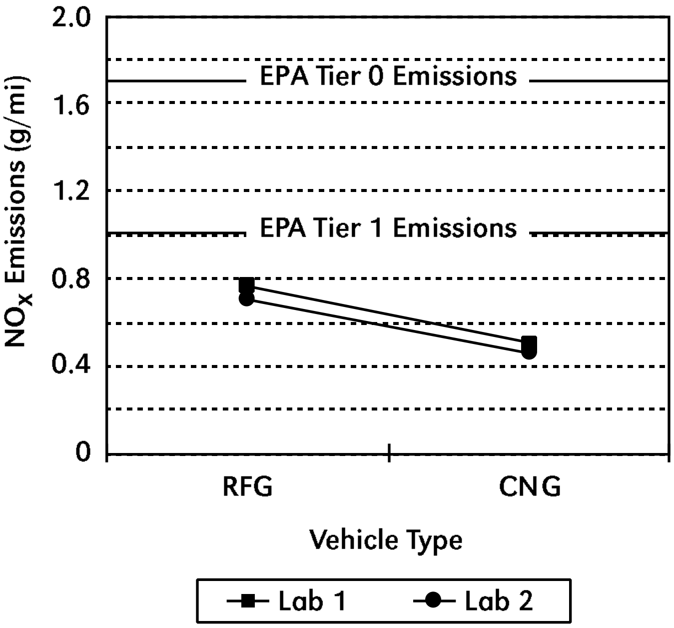


Figure 15. Comparison of NO_X emissions from the two types of vehicles, by lab

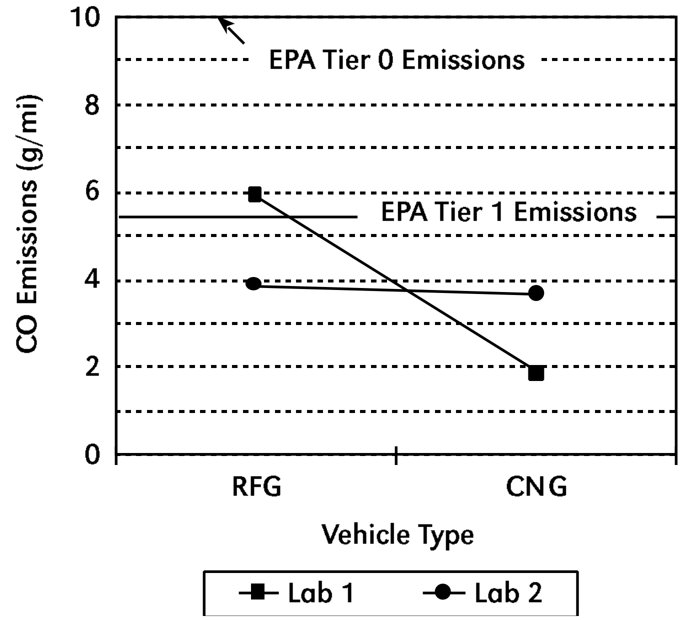


Figure 16. Comparison for CO emissions from the two types of vehicles, by lab

constituents, both labs showed considerably lower emissions from the CNG tests compared to the RFG tests. For CO, there was considerable difference between the labs.

Evaporative Emissions

A comparison of total evaporative hydrocarbons (THC) measured on the two types of vehicles by the two laboratories is presented in Figure 17. Note, although CNG vehicles theoretically have a sealed fuel system (i.e., no evaporative losses), the THC shown here was measured when the vehicle was placed in the sealed housing for evaporative determination. Average evaporative THC reported from CNG vans is lower by a considerable margin than the corresponding average value reported from gasoline vans (a range of 0.83–0.57 grams per test for the two labs versus a range of 0.59–1.42 grams per test for the two labs, respectively).

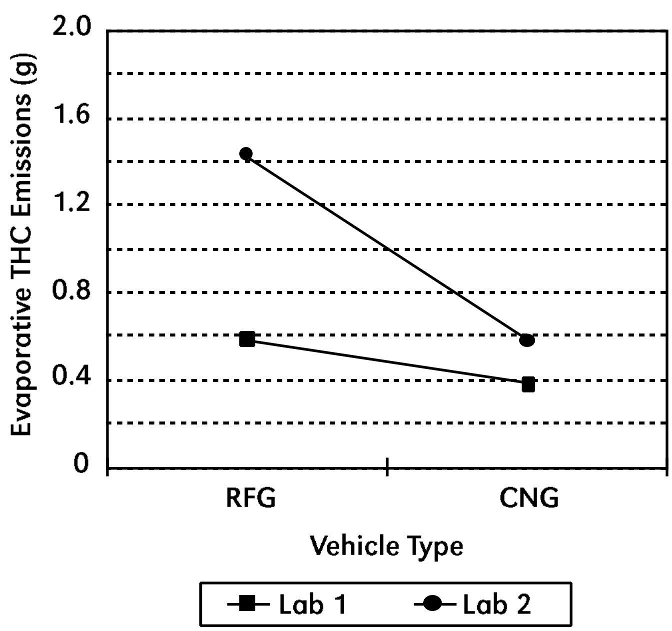


Figure 17. Comparison of evaporative THC measured on the two types of vehicles, by lab

Speciation of Hydrocarbon Emissions

Speciation, or quantification of individual HC emissions components through gas chromatography, was performed on two CNG and three standard Dodge B250 vans.

Exhaust Toxics

Figures 18 through 21 present vehicle-type comparisons of the four mobile source toxic exhaust compounds. In all cases except for formaldehyde, the results show that the levels of toxic compounds emitted from the CNG vans are substantially lower, on average, than those from the gasoline vans. Formaldehyde emissions are dominated by one of the two CNG vehicles with high formaldehyde results. This is the same vehicle that exhibited higher than expected CO, although no performance problems were noted. Similarly, the average of the aggregated toxic emissions for the CNG vans is 7.47 mg/mi;it is 16.31 mg/mi for the gasoline vans.

Ozone-Forming Potential and Specific Reactivity

Ozone precursor data are reported in terms of OFP and SR. Figures 22 and 23 show the respective comparisons for these two quantities for the two types of vehicles. In this study, OFP and SR are both substantially lower, on average, for the CNG vans than for their gasoline counterparts.

CNG Summary of Results

For each of the quantities discussed above, Table 6 shows the percent change in the average results reported for the CNG vans relative to their gasoline counterparts.

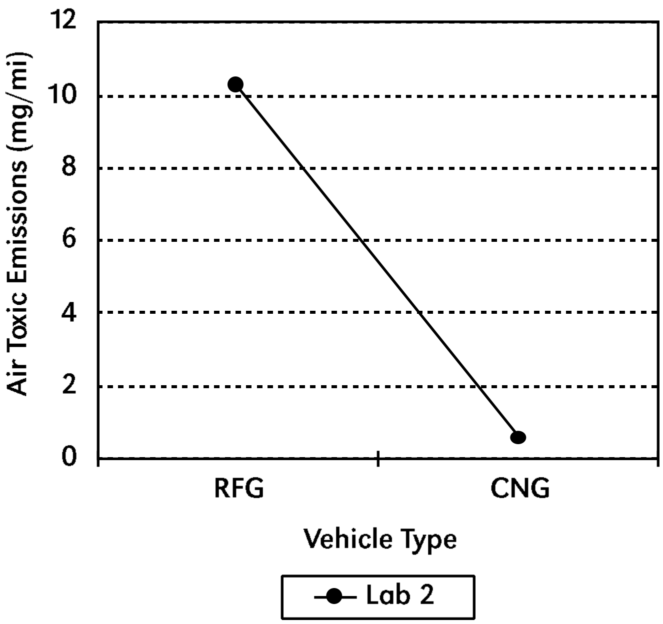


Figure 18. Comparison of benzene emissions from the two types of vehicles, Lab 2

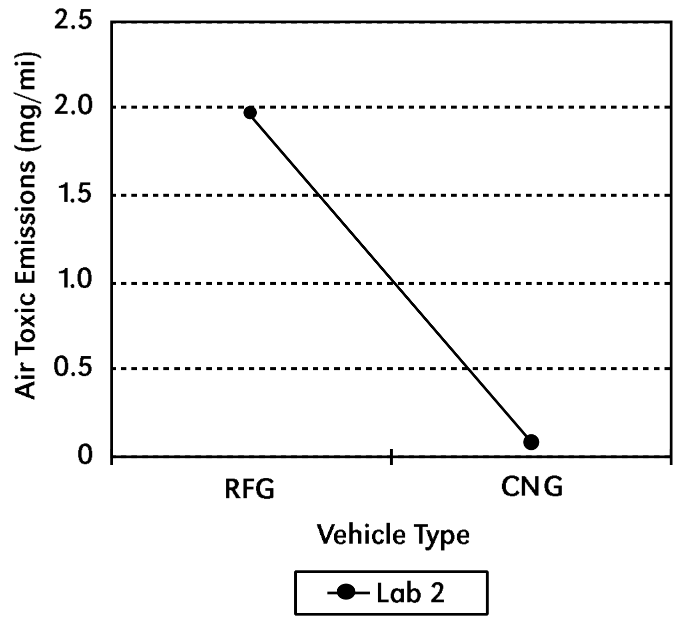


Figure 19. Comparison of 1,3-butadiene emissions from the two types of vehicles, Lab 2

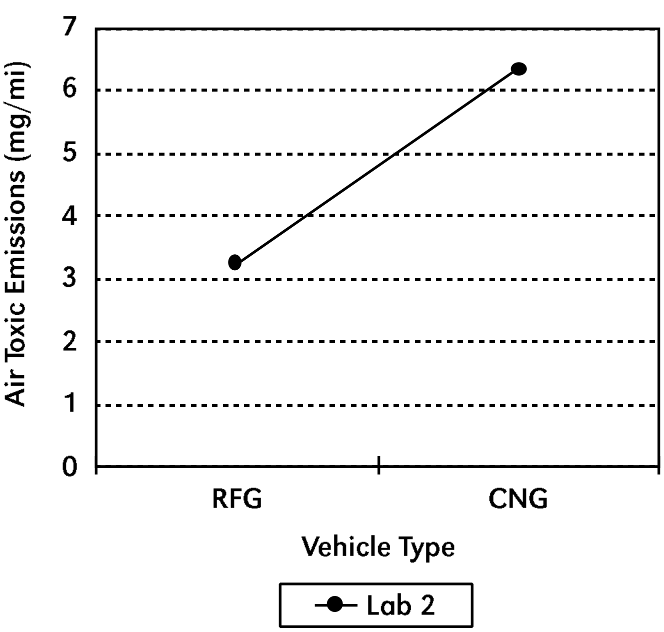


Figure 20. Comparison of formaldehyde emissions from the two types of vehicles, Lab 2

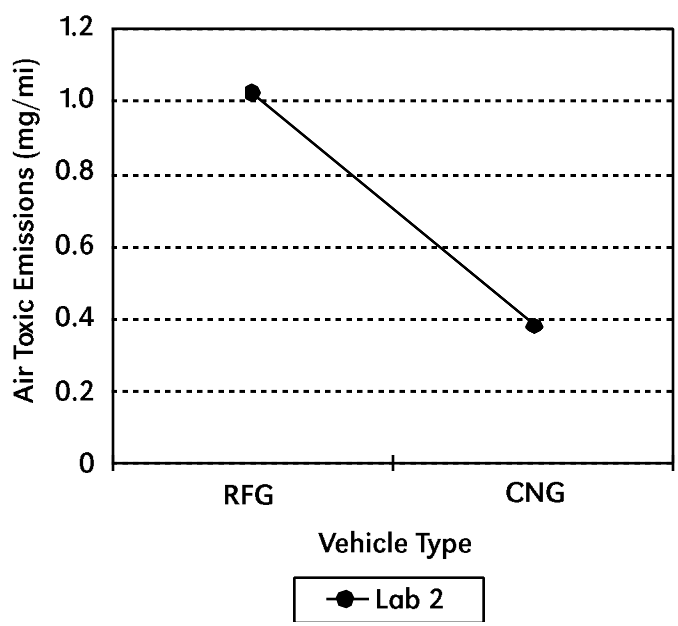


Figure 2 1. Comparison of acetaldehyde emissions from the two types of vehicles, Lab 2

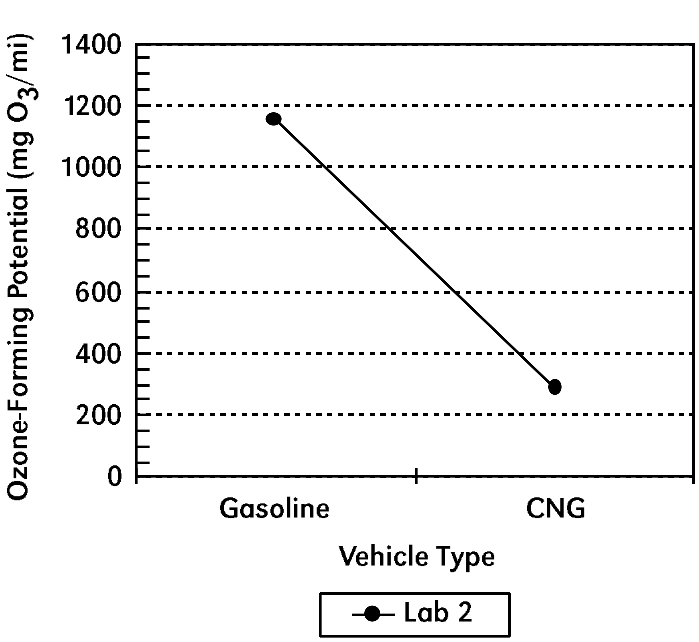


Figure 22. Comparison of OFP calculated for the two types of vehicles, Lab 2

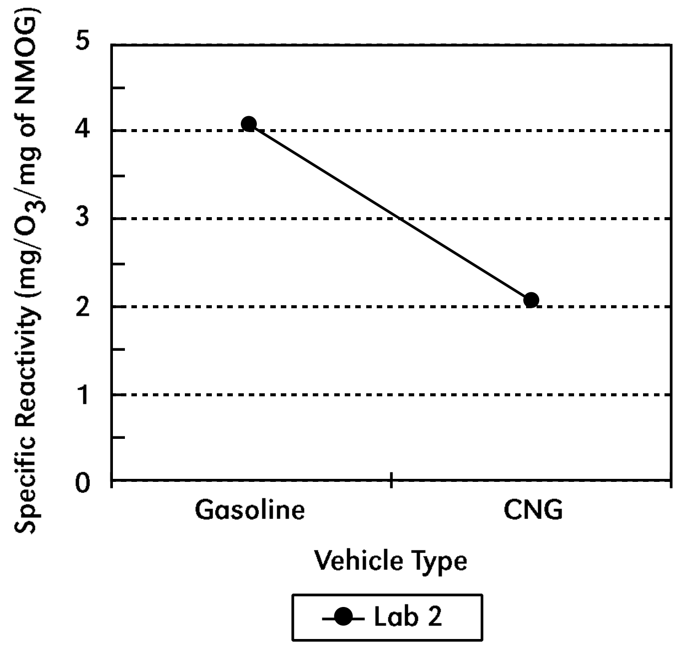


Figure 23. Comparison of SR calculated for the two types of vehicles, Lab 2

For More Information

All data (bag-specific, exhaust, evaporative, and hydrocarbon speciation) from the testing of light-duty alternative fuel and standard gasoline vehicles can be found in the Alternative Fuels Data Center (AFDC). The AFDC is accessible via the World Wide Web at the following Internet address: http://www.afdc.doe.gov.

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*Table 6. Summary of Effects for CNG Compared to RFG**

	Lab 1	Lab 2
Fuel economy	-11.9%	-3.2%
NMHC	-83.3%	-76.9%
NO_x	-30.8%	-31.4%
CO	-65.9%	-2.9%
CO_2	-15.5%	-18.9%
Evaporative HC	-35.6%	-59.9%
Toxics		
- Benzene	-96.0%	
- 1,3-Butadiene	-94.8%	
- Formaldehyde	48.0%	
- Acetaldehyde	-61.8%	
Specific Reactivity	-50.0%	
Ozone-Forming Potential	-74.4%	

*Note that negative values represent a reduction in emissions from CNG over RFG, and positive values represent an increase.

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